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Fibers—
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## CEH Marketing Research Report

# RAYON AND LYOCELL FIBERS

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The global demand for rayon over the next five years should stay in the 1.8-2.0 million metric ton-per-year range. Rayon usage in Asia has been supplemented with cotton. Domestic rayon fiber demand in the various other regions, for the most part, is expected to remain close to 1999 consumption levels in the near term.

## INTRODUCTION

Rayon fiber is defined by the U.S. Federal Trade Commission as "a manufactured fiber composed of regenerated cellulose, as well as manufactured fibers composed of regenerated cellulose in which substituents have replaced not more than 15% of the hydrogens of the hydroxyl groups" (*Rules and Regulations Under the Textile Fiber Products Identification Act*, U.S. Federal Trade Commission).* Substituents consist of manufacturing impurities, pigments, fire retardants or other additives. This report covers the following types of commercially available rayon fibers: viscose, polynosic and cuprammonium rayon produced in regular-tenacity staple and filament, high wet modulus staple and high-tenacity filament.

Lyocell fiber, the newest member of the cellulosic fibers, is manufactured directly from high-purity cellulosic wood pulp, whereas rayon is manufactured from a cellulose derivative that is chemically "regenerated" back to cellulose during the spinning process.

Rayon was the first man-made fiber. In 1924, the name "rayon" was adopted officially by the National Retail Dry Goods Association; before that time, it had been termed artificial silk, fiber silk, wood silk or viscose silk.

Rayon fibers are a diverse group, all consisting of regenerated cellulose derived from wood pulp. Basic fiber properties of rayons vary, particularly in regard to wet and dry tenacity, elongation, elastic recovery, water and alkali swelling and, to some extent, abrasion resistance. They have certain characteristics in common that are attributable to their cellulose composition: they are hydrophilic, swell in water and alkali, are receptive to essentially the same dyes as cotton and, when heated, decompose without melting.

As with all fibers, the degree of polymerization and molecular orientation (crystallinity) controls the strength properties (e.g., the tenacity). Properties such as wet strength, dye uptake, moisture absorption and swelling behavior, as well as resilience and hand, can vary considerably among different types of rayons. Possible cross-linking or other chemical modification in the skin of the fiber, as well as the shape of its cross-section, can have additional effects on fiber properties. These variables are controlled to a large extent by spinbath compositions and spinning methods, as well as chemical modification, thus allowing rayon its wide range of performance properties.

## REGULAR RAYON FIBERS

Regular rayon fibers were the first-generation fibers produced. The wood cellulose used for regular or conventional rayon has a relatively low degree of polymerization (500-1,000 repeating cellulose units) and a cellulose purity of 90-92%, enabling the use of hardwood pulp raw material.

* The percentage (15%) is low for fire retardant–treated fibers.

## CUPRAMMONIUM RAYON FIBERS

Cuprammonium rayon fibers are made from a cellulose solution, produced from wood pulp or cotton linters dissolved in a cupric oxide–ammonia solution. Fibers are extruded (wet-spun) from the solution, then coagulated, stretched, treated with acid to remove the copper residue, washed and dried. After dyeing, cuprammonium rayon is characterized by unusual softness, high luster and brilliant color; its physical properties closely resemble those of regular rayon. The fiber is made only in Japan, Italy the former USSR and China.

A comparison of rayon staple fiber properties by fiber type is shown in the following table:

**Typical Properties of Rayon Staple Fibers[a]**

| | Regular Rayon | High-Tenacity Rayon | High Wet Modulus Rayon | Polynosic Rayon | Lyocell (solvent-spun cellulosic) |
|---|---|---|---|---|---|
| Tenacity (grams per denier) | | | | | |
| Dry | 2.2-2.5 | 2.8-3.8 | 3.5-5.0 | 4.0 | 4.8-5.0 |
| Wet | 1.1-1.5 | 1.9-3.0 | 2.3-3.3 | 2.8 | 4.2-4.6 |
| Elongation (%) | | | | | |
| Dry | 22 | 18-24 | 15-24 | 10 | 14-16 |
| Wet | 28 | 22-32 | 18-26 | 12 | 16-18 |
| Specific Gravity | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Moisture Regain (% at 21°C and 65% RH) | 11-12 | 12 | 12 | 12 | na |
| Degree of Polymerization | 300 | 300 | 300 | 500 | na |
| Degradation Point (°C) | 177 | 177 | 177 | 177 | na |

a. Physical properties depend on manufacturing conditions and chemical composition as well as on test methods and test conditions. Therefore, these data should be used as guides for comparative evaluation rather than as exact values.

SOURCE: Company product bulletins.

## LYOCELL FIBERS

Solvent-spun cellulosic fibers were commercialized in the early 1990s and are generically designated as lyocell in the United States and in Europe. Lyocell fibers represent a breakthrough in the technology and manufacture of cellulose fibers. Solvent-spun cellulosic fibers are derived from alpha-grade cellulose pulp, which is dissolved in a solvent (N-methyl morpholine oxide) and wet-spun into a bath; the N-methyl morpholine oxide is recovered from the bath. Because lyocell cellulosic fibers have not been modified by attached chemical groups such as cellulose acetate fibers and they meet the USFTC definition of a cellulosic rayon fiber, they are included in the body of this report. Solvent-spun cellulosic rayons are high-strength fibers that are strong even when wet and exhibit better abrasion resistance, moisture absorbency and dye affinity than regular or polynosic rayons. These fibers are produced in the United States, the United Kingdom, Austria and Germany.

# MANUFACTURING PROCESSES

## FIBER MANUFACTURE

Rayon fibers are made from chemical cellulose (dissolved wood pulp), sodium hydroxide, carbon disulfide and sometimes modifiers, which are usually based on ethoxylated natural fatty acid amines. Most rayon is made by the viscose process; however, some specialty rayon is made by the cuprammonium process in Italy, the former USSR and Japan and by the solvent-spun process in the United States, the United Kingdom and Austria.

In the manufacture of the various viscose (wet-spun) rayon fibers, the same basic process is used. However, a number of important variables in the viscose process can be manipulated to obtain fibers of substantially different characteristics. Broadly speaking, the main fiber categories include regular (conventional) rayon, modified high-tenacity rayon, high wet modulus rayon and polynosic rayon.

The raw material for viscose rayon, chemical cellulose (commonly known in the industry as dissolving wood pulp), is characterized by a relatively high content of alpha-cellulose. It can be either hardwood or softwood pulp as long as the alpha-cellulose content is sufficiently high. This pulp, in either sheet or bulk form, is purified by the rayon manufacturer by converting it to an intermediate (alkali cellulose) that can be dissolved; it is then formed into a fiber. At this point, the cellulose is regenerated, but to a degree of polymerization that is only 25-50% that of the original cellulose. The higher the degree of polymerization of the fiber, the better the fiber's performance properties and the higher the cost of the process.

In the first step, the wood pulp is treated with an excess of a rayon-grade sodium hydroxide solution.* This purification step extracts the alkali-soluble impurities and produces alkali cellulose.

$$(C_6H_{10}O_5)_n \;+\; n\,NaOH \longrightarrow ([C_6H_9O_4]ONa)_n \;+\; n\,H_2O$$

| | | | | |
|---|---|---|---|---|
| | cellulose | sodium hydroxide | alkali cellulose | water |
| mol wt: | $(162)_n$ | 40 | $(184)_n$ | 18 |

Unreacted alkali (steeping liquor) is pressed out of the cellulose and the alkali cellulose is shredded. It then undergoes oxidative depolymerization (aging) under carefully controlled conditions of temperature, surrounding atmosphere, catalysts and duration. When the product has aged to the desired degree, it is reacted with carbon disulfide to form a xanthate. Xanthation is a batch process in an airtight reactor with a vacuum assist. The amount of carbon disulfide used is an important process variable.

$$([C_6H_9O_4]ONa)_n \;+\; n\,CS_2 \longrightarrow ([C_6H_9O_4]O\overset{\overset{\displaystyle S}{\|}}{C}SNa)_n$$

| | | | |
|---|---|---|---|
| | alkali cellulose | carbon disulfide | sodium cellulose xanthate |
| mol wt: | $(184)_n$ | 76 | $(260)_n$ |

* Rayon-grade sodium hydroxide is especially low in iron and manganese, elements that cause viscosity control and color problems.